ESP-CARRIERS-OCD-001

455 / EXPLORATION SYSTEMS PROJECTS

Exploration Carriers Initiative

Concept of Operations

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Preface

This document describes the Concept of Operations for the Exploration Systems Mission Directorate's (ESMD) Exploration Carriers Initiative, as managed by the Goddard Space Flight Center (GSFC), Exploration systems Projects, Code 455.

This is a companion document to the Exploration Carriers Initiative Statement of Objectives ESP-CARRIERS-SOO-001) which summarizes Exploration Carriers capabilities for potential secondary payload customers.

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1. Introduction

NASA has begun development of its most ambitious program for human space exploration to date. The Constellation Program (CxP) architecture not only preserves the United States' access to Low Earth Orbit (LEO), but provides a platform for a return to the Moon, and a foundation for human exploration of Mars and beyond. As such, the Constellation architecture represents the "next generation" of human spaceflight systems.

The United State's manned spaceflight programs addressing delivery to LEO - Apollo, Space Transportation System (aka., Space Shuttle Programs) - allowed unprecedented access to space for the United States and its partners. These programs carry a long history of delivering small secondary payloads to orbit in an effort to further specific scientific and engineering objectives, thereby maximizing the nation's investment in the Apollo and Space Shuttle programs.

NASA's Exploration Systems Mission Directorate (ESMD) recognizes the extensibility of these proven and successful concepts to NASA's newest architecture for human space exploration, the Constellation architecture. To fully leverage the lessons of Apollo and the Space Shuttle, the adaptation of any space architecture to carry secondary payloads must extend to the new set of vehicles and missions within the ESMD space program. In this way, NASA ensures continued availability of a delivery mechanism for small attached payloads, thereby providing user communities with routine, rapid, low-cost access to space.

The Exploration Carriers Statement of Objectives cites the national need for routine, low-cost, low-risk opportunities for Constellation secondary payload capabilities to serve Principal Investigators (PIs) from academia, industry and government agencies. In support of that need, Exploration Carriers incorporates secondary payload capabilities throughout the architecture as the next major human spaceflight system. Exploration Carriers has three main objectives;

- Fly Exploration Carriers payloads in the Service Module of the Orion starting with Orion 1, the first Orion mission.
- Establish a Missions Operation Center and Science Operations Center at GSFC
- Develop interfaces and compatible concepts for all Constellation flight elements

This Concept of Operations (CONOPS), along with companion documents, will establish the project framework, implementation approach, and operational constraints for the Exploration Carriers Initiative, defining a standard set of processes, and offering an extensible capability that will grow as Constellation matures. GSFC's Exploration Systems Projects is the organization that will manage and operate Exploration Carriers for NASA.

Figure 1-1: Exploration Carriers Opportunity below illustrates NASA's overall payload launch capability as it currently exists, and highlights the specific niche that Exploration Carriers intends to fill; balancing risk and cost by providing secondary payload capability within the CxP architecture. Exploration Carriers addresses a critical need to provide cost-effective access to space for systems in the Venture-class or SMEX-class range.

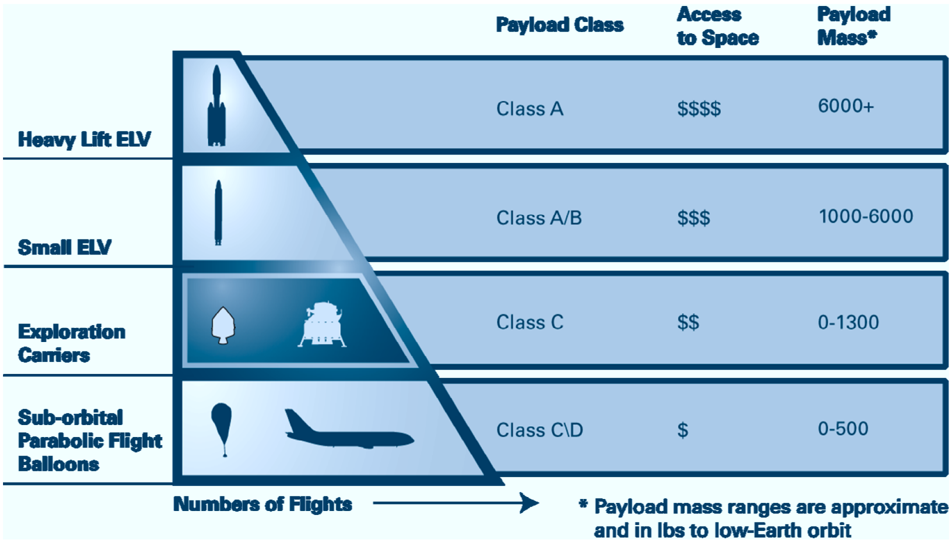


Figure 1-1: Exploration Carriers Opportunity

This CONOPS addresses an agency need to accommodate science and technology payloads via the Exploration Carriers national asset. Exploration Carriers capability is currently expressed in terms of what type of payload can be delivered via the Constellation program to Low Earth Orbit and beyond. As shown in Figure 1-2, this CONOPS focuses on early stages of the project life cycle: identifying mission scenarios, integration and operations processes, and potential payload physical envelopes. The intent of the CONOPS is also to address interfaces between the Exploration Carriers user community and the Constellation Program. By defining the basic mission set and program capabilities, mission-specific requirements and capabilities for components of the Constellation architecture can be subsequently derived.

Figure 1-2: Carriers Initiative CONOPS relative to the development life cycle

Exploration Carriers seeks to provide a quick reaction scientific and technology payload delivery asset that takes advantage of Constellation capability and evolves with Constellation hardware definition and development.

Figure 1-3 shows various elements of the Constellation Program. The first instantiation of Exploration Carriers payload accommodation will utilize the Orion spacecraft - to be launched by the Ares I launch vehicle - for delivery of payloads to environments useful for science and technology development. Once the Orion design matures, a Payload Implementation Plan will be prepared such that detailed mission scenarios can be developed. This will include detailed payload integration processes and schedules, the vehicle constraints and restrictions, and a representative mission timeline which documents the entire Carriers life cycle, from preliminary design through mission operations, data gathering and distribution, and payload retirement.

The Exploration Carriers Initiative vision is to provide science and technology payloads affordable access to space, while maximizing the nation's investment in the Constellation Program on a non-inference basis. Initially, the focus will be on the use of the Orion spacecraft to deliver payloads to Low Earth orbit (LEO), including delivery to the International Space Station (ISS).

Exploration Carriers provides a unique programmatic model where science and technology development projects have a single interface for integration, launch, operations, data transfer and dissemination, and disposal. Exploration Carriers will provide necessary mass, volume, power, thermal, and data interface specifications within the Orion vehicle and Ares I unpressurized volumes to deliver payloads to their desired destination. Exploration Carriers can be considered the "travel agent" for small payloads, providing centralized functions and services that would be not be cost-effective for users to recreate.

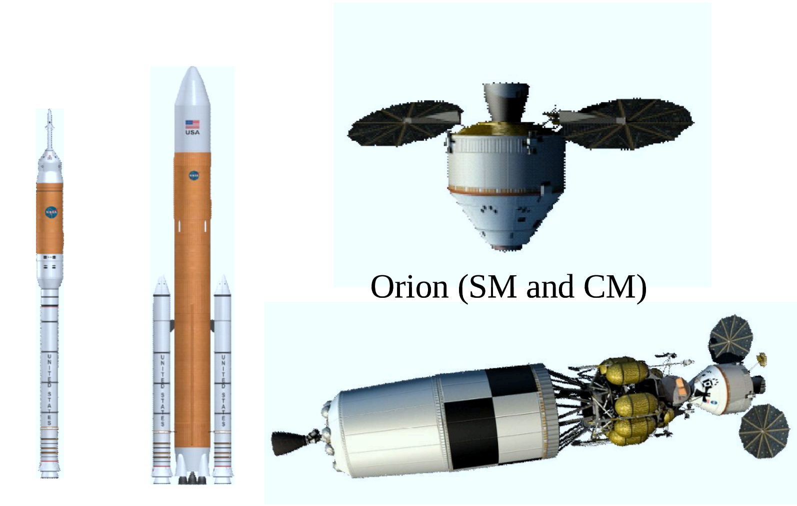


Figure 1-3: Constellation Program elements

1.1 Background

Exploration Carriers builds on a rich history of maximizing NASA's capability of its human spaceflight architectures. The Apollo SIM Bay was located on the Apollo Service Module and flew on the Apollo J missions (Apollo 15, 16 and 17). It carried 11 scientific and exploratory experiments designed for operation in Lunar orbit, including two different types of film cameras and numerous spectrometers used for characterizing the lunar surface. The SIM Bay on Apollo 15 and 16 also ejected a 78 pound sub-satellite, which carried three scientific experiments into lunar orbit. These experiments included a laser altimeter to measure the heights of lunar surface features as well as instruments to measure variations in the Moon's gravitational acceleration and the structure of the upper layers of the lunar crust. In total, the Apollo SIM Bay science experiments enabled an opportunity to gain important science benefits that directly benefited future missions to, and study of, the Lunar surface.

Under GSFC management, the Shuttle Small Payloads Project (SSPP) continued this tradition into the Space Transportation System era. Two specific types of secondary payload experiment opportunities were used on the Space Shuttle, beginning with STS-4 in 1982. This project provided quick reaction space mission capability for low cost to the scientific and engineering community through a standardized, repeatable process. GSFC provided end-to-end engineering and management services for SSPP customers, enabling Principal Investigators to focus on their instrumentation and science.

- The Hitchhiker project provided opportunities for experiments to fly in the Shuttle payload bay. The carrier system utilized by Hitchhiker was modular in order to increase flexibility for potential payloads while still maintaining standardized mechanical and electrical interfaces. These experiments could also rely on astronaut support to carry out their objectives such as requiring specific shuttle maneuvers or astronaut participation during experiment operations.
- Space Shuttle Get Away Special (GAS) payloads were similar to Hitchhiker missions, but did not rely on shuttle power and included only minimal astronaut intervention for successful completion. These were typically small experiments that were self contained in standard sized containers and loaded into the Shuttle payload bay.

SSPP took advantage of the significant capability offered by the Space Shuttle Program to provide quick, reliable, and affordable access to space for small payloads. This program enabled hundreds of secondary payloads to fly in space, at low marginal cost. These projects supported 76 different instruments on 26 different flights. GSFC established a smooth, successful process to integrate, fly, and operate these payloads.

1.2 Benefits

The Exploration Carriers Initiative will provide critical services to science and technology payload customers, and offers the following benefits:

- Maximized science and technology payload capabilities for the Constellation program architecture by ensuring a sufficient payload volume to accommodate a number of mission scenarios (deployment of a free flyer, extraction to the ISS environment, fixed pallet capability).
- Single interface approach
  - Established, repeatable programmatic interfaces and processes
  - Single programmatic interface for the user community uses a “plug and play” physical interface and established programmatic interfaces
  - Leverages the attached payloads efficiencies validated during the Apollo (SIM Bay) and Shuttle eras (GAS, and Hitchhiker).
  - Provides a capability that as a payload is fully developed and ready for Orion integration, a launch opportunity can be available within 4 months.
- Reduces technical and program risk
  - Exploration Carriers manages the provider-to-carrier interface, not the users: applies for all Constellation architecture elements, from Orion to Altair to the Earth Departure Stage (EDS)

    - Safety, integration and mission operations interfaces and established carriers

- A standardized set of space access capabilities (selectable by need) with defined physical envelope and environment (mass, power, thermal, data, vibration, noise, etc.) with capability to reach all Constellation destinations – from LEO to the Moon and Mars
- For fixed pallet missions (missions which stay with the Orion vehicle for the durstion of the flight) , the host platform provides sustaining power and data recording and transfer to a mission operations center for full mission support, data receipt, and data distribution

1.3 Additional Exploration Carrier Initiative Opportunities

The goal is to take advantage of the capability offered by Constellation to conduct useful science and technology investigations while not disturbing the core mission of human spaceflight. Minimal impact is envisioned to Orion for all operations accommodating deployable, extractable, and pallet style missions .

One consideration is the necessity of an industry education effort so that commercial, government, and educational entities can respond quickly to a defined "User's manual" set of expectations to enter into the Exploration Carriers mission set, and to secure funding to guarantee participation for an allocated launch opportunity. In all user forums to date, the community response has been positive and strong.

Additionally, Exploration Carriers will align Constellation architecture science and technology payload capabilities with the small satellite (smallsat) industry to help provide potential mission opportunities for these customers as well.

2. Operational Considerations

Exploration Carriers will use cargo capability baselined in various components of the Constellation architecture, such as the Orion Service Module, to provide capability to the science and technology community. Operational considerations reflect parameters and assumed limits based on preliminary mission analysis conducted by the GSFC Mission Design Lab, to guide future refinement efforts for requirements and help develop operations approaches. This section addresses payload envelopes for different missions, as well as operating assumptions and considerations based on GSFC's past experience with Hitchhiker and an analysis of existing Exploration and Constellation requirements.

2.1 Guiding Assumptions

Exploration Carriers is not intended to be a significant driver of Constellation requirements in general, nor is it intended for Carriers to substantially drive Orion design. Accordingly, any Carriers focus on Exploration Architecture Requirements Document (ESMD-EARD 08.07 Rev A) which are level 1) or CxP70000 Constellation Architecture Requirements Document (CARD which is Level 2) be limited to providing basic accommodations for Carriers payloads, using existing host vehicle capabilities.

2.2 Payload envelopes

GSFC's Exploration Systems Projects is responsible for defining the Carriers payload envelope for each Constellation platform opportunity, in conjunction with the respective Constellation project office, based on the specific Constellation component design and the appropriate mission set. Initially, payload envelopes for the Orion spacecraft have been developed, covering both the LEO/ISS and lunar mission sets. The payload environment consists of:

a. Volume

b. Mass

c. Power

d. Thermal loads

e. Avionics standardized SM interface

    1. Command and Data Handling

    2. Communications

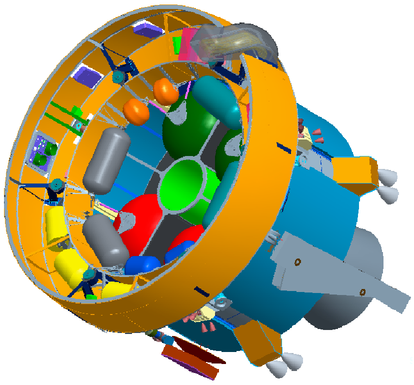
f. Mechanical loads, to include launch loads

g. Acoustics

h. Integration processes

i. Mission duration

Figure 2-1 below shows a model of the available cargo space on the ISS mission configuration of the Orion Service Module. Figure 2-2 shows the carriers capability on the lunar configuration of the Orion SM, known as the Orion SIM Bay.



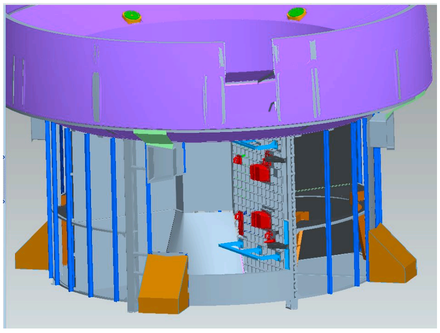


Figure 2-1: CAD model of the Orion Service Module for Exploration Carriers

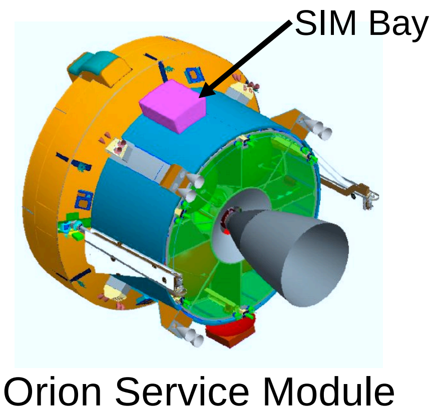


Figure 2-2: Orion SIM Bay Capability Figure

2.3 Operations approach and interfaces

It is Exploration Carriers' mission to provide not only a customer payload integration capability, but to have the "One Stop Shop" approach continue through Integration and Test (I&T) operations, launch support services, mission support, and when applicable, data reception, distribution, and archive. To further ensure this complete integration of services approach, Exploration Carriers will employ:

- A sound and proven Ground Data System architectural design
- A single programmatic interface to a science operations center for all Carriers services

- A Mission Operations Center (MOC) design building on established successes with previous programs
- An operational timeline that accommodates any viable scientific or technical quick reaction secondary payload of opportunity

2.4 Operation Centers

Exploration Carriers will provide its users with a single operational interface for the entire system lifecycle, supporting payload integration, mission operations, and disposal. Exploration Carriers will establish a Mission Operations Center (MOC) at GSFC to serve as the interface to the Mission Control Center created by the Constellation Program and located at Johnson Space Center. In addition, Exploration Carriers will establish a Science Operations Center at GSFC which will route data to mission-specific destinations in the science and technology community, as well as meet data integrity requirements. The communication architecture includes these operational centers as shown in Figure 2-3 and described below.

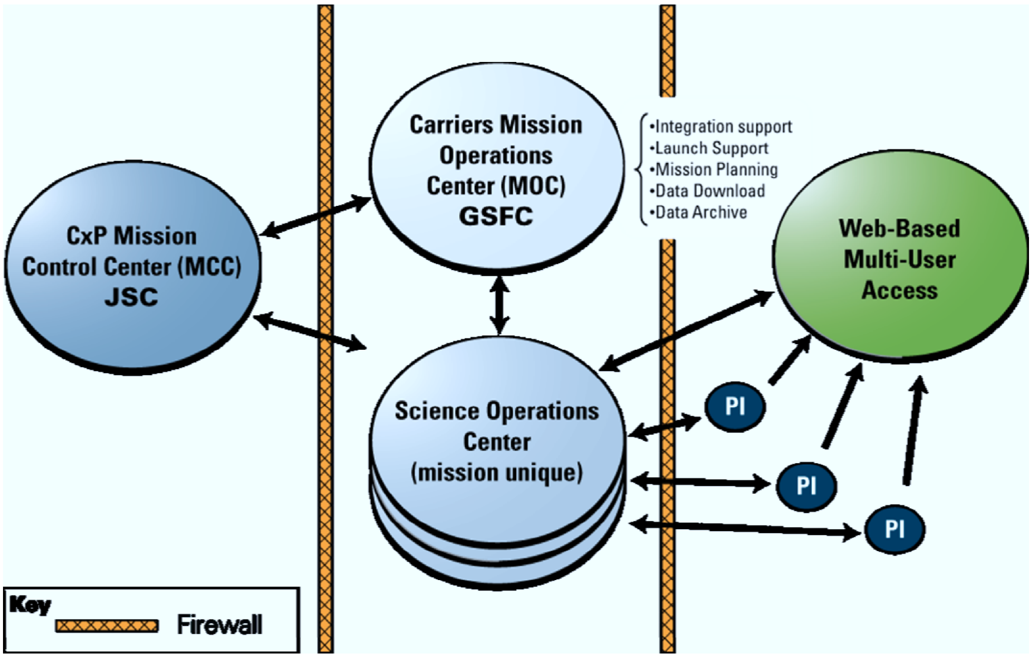


Figure 2-3: Operations Center Relationships

2.4.1 Mission Control Center (MCC)

The Constellation MCC is located at Johnson Space Center (JSC) and manages all aspects of CxP missions. This includes issuance of commands to the launch vehicle and spacecraft, including Orion, as well as reception of telemetry and mission data. For Exploration Carriers payloads, the MCC will serve as a pass-through for pre-approved commanding, housekeeping telemetry, and mission data. The MCC provides the only direct link to any secondary payload riding on any Constellation vehicle for Exploration Carrier purposes.

2.4.2 Mission Operation Control (MOC)

Exploration Carriers provides a MOC that serves as the single operational interface for payload users. Located at GSFC, the MOC provides a standard set of telemetry, tracking and command functionality as the Exploration Carriers interface to the Mission Control Center for the payload being flown. The MOC provides support to Exploration Carriers users throughout their lifecycle, from provision of a standard mission interface, through integration, testing, and operations. Exploration Carriers MOC functionality is listed below in Table 2-1 .

Table 2-1: Details of MOC Functionality

GSFC MOC functions
Flight Dynamics – attitude and orbit
Integration and Test support
Health/safety processing
Commanding
Mission scheduling
Data handling & distribution
Trending/Analysis
Mission planning
Network & contact schedule
Carrier payload monitor/control
Mission Ops testing
Navigation/anomaly investigation
Pass scheduling
Ops Autonomy
MOC/SOC payload troubleshooting

2.4.3 Science Operations Center (SOC)

Exploration Carriers provides a SOC that serves as the single operational interface to the MCC for science data receipt. Located at GSFC, the SOC provides a standard set of data capture, simple archive, and data forwarding functionality for the payloads. Principal Investigators may elect to use the SOC for Level-0 and higher-level data processing but these functions will be considered mission-specific and funded by the investigator.

3. Mission Sets

The potential exists to utilize all orbit regimes that Orion will visit, including LEO, ISS, trans-lunar, lunar orbit, and ultimately a Mars trajectory. Figure 3-1 shows a representation of an Orion visit to the ISS. Though most scenarios have been investigated on a preliminary feasibility basis, to date only detailed payload margins have been developed for the LEO mission set.

Figure 3-1: Artist rendering of Orion mission to ISS

3.1 Low Earth Orbit/ISS

Figure 3-2 represents an Orion Design Reference Mission (DRM) to the ISS to deliver Orbital replacement Units (ORUs) , and/or science and technology payloads that make use of the ISS environment. These missions have been bounded using a Control Moment Gyro (CMG) ORU as an example of a typical payload delivered to ISS orbit (see Figure 3-3). When ORUs are not required by the ISS the manifest is then open to use this capability for secondary science and technology payloads ..

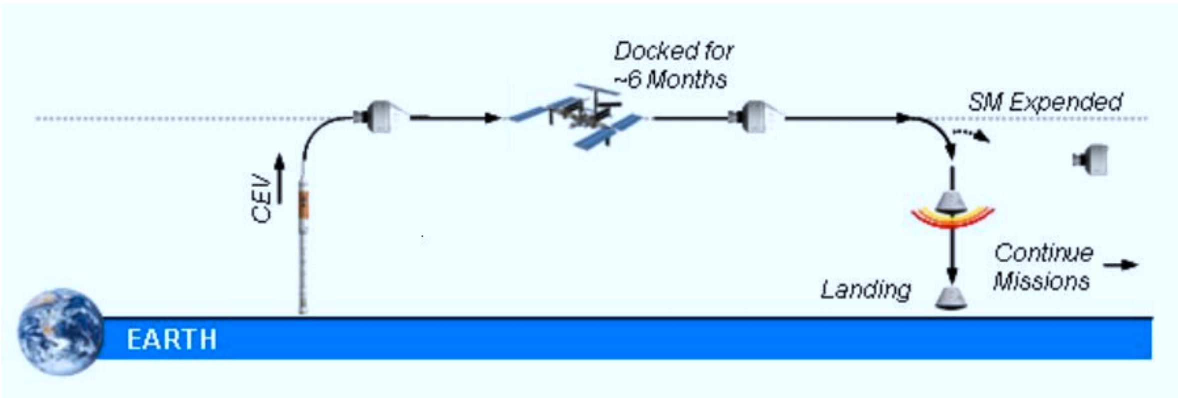


Figure 3-2: : ISS Design Reference Mission

Mission options to LEO accommodate several mission options; extraction of an Exploration Carriers secondary payload to the ISS, deployment/ejection of a free flyer in LEO, and a fixed pallet option that remains with Orion for the mission duration.

3.1.1 LEO/ISS – Extraction to ISS

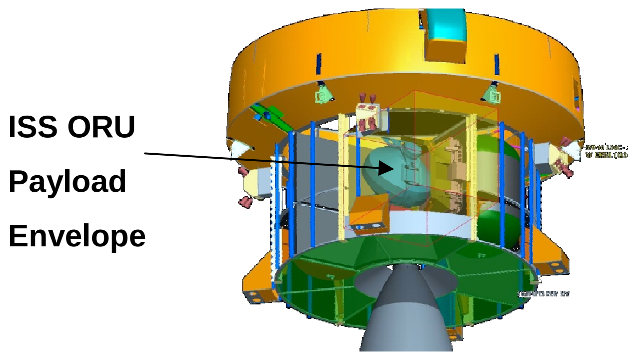


Figure 3-3: ISS Extractable payload accommodation.

Payload extraction. During an ISS rendezvous mission, a payload is extracted from Exploration Carriers via the Space Station Remote Manipulator System (SSRMS) and placed on the ISS to complete its mission.

The Exploration Carriers LEO option includes Venture and SMEX class payloads, and will use interfaces common with other launch systems.

Main goals of payloads extracted from Orion for an ISS mission include;

- Science investigation and technology demonstration
- External facility sites (JAX's JEM-EF, ESA Columbus module)

This type of payload can take advantage of long mission duration and potential for return to Earth at mission end.

3.1.2 LEO/ISS – Free Flyer/ejection payload

Payload ejection. This mode involves any payload that is deployed/ejected from the Constellation vehicle after it reaches LEO. Figure 3-4 depicts the potential payload envelope for an ejectable/deployable free flyer. Upon release the payload becomes a free flyer, continuing its mission independent of Orion. At a pre-defined point in the mission timeline, MCC responsibility for the mission concludes and the MOC/SOC will interface directly with the payload for the remainder of the mission. Until that demarcation is encountered, the SM provides avionics support as well as stable power and thermal environments, much as would be supplied by a typical launch vehicle.

The total mass to orbit (approximately 600 Kg) includes the deployment/ejection mechanism. It also must accommodate the physical constraints of the access panel which allows clean deployment from the Orion vehicle.

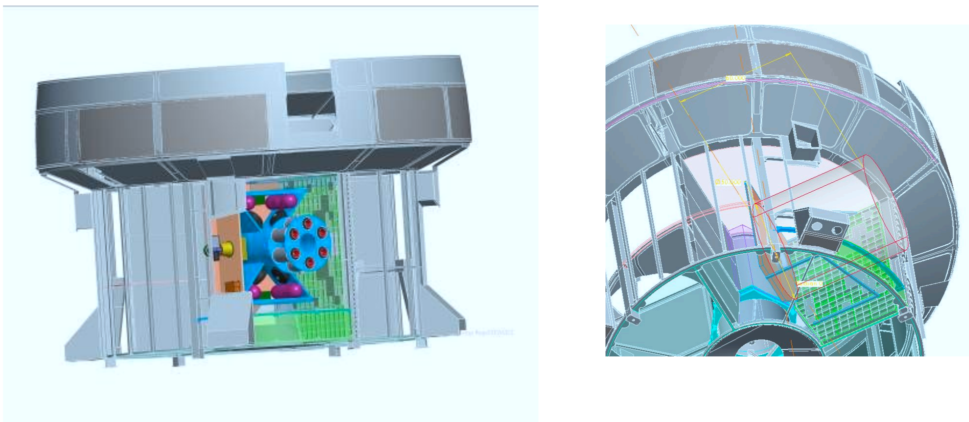


Figure 3-4: LEO ejectable/deployable payload accommodation

3.1.3 LEO – Fixed Pallet

Payload fixed pallet. A payload is fixed to a standard interface structure and remains with the Orion vehicle for the entire mission. This is the simplest mission to accommodate and affords the payload the greatest mass allocation, though clearly the mission ends on re-entry, and all data must be collected and archived prior to mission end.

Fixed pallet payloads include test equipment and instrumentation (sensors, detectors, cameras) to help fuly characterize the in-situ flight environment. The missions accommodate up to a six month duration of data collection prior to SM reentry into Earth's atmosphere.

3.1.4 LEO/ISS Payload Envelope

Orion crewed and uncrewed missions to LEO, including missions to ISS, provide the first opportunity for Exploration Carriers. Table 3-1 below describes the envelope parameters for a Carriers mission to LEO/ISS aboard Orion. The described payload envelope includes the Carriers payload, as well as mission kits that might include mechanical elements, thermal blankets, and/or release mechanisms. Actual Carriers envelope information for a specific Orion flight will be determined by the primary Orion mission parameters (i.e., intended orbit, crew size, etc.).

Table 3-1: Orion LEO Mission Payload Envelope

Orion LEO/ISS Missions			
Parameter	**Capability**	**Source**	**Comments**
Orbit	**52^{o} inclination**	Standard ISS inclination	ISS launch assumed for mass capability
Duration	**Variable**	CxP 70007 (Design Reference Missions) and Carriers MDL studies	Dependent on payload configuration, location, and deployment
Mass	**< 600 Kg**	Cx 70000 Constellation Architecture Requirements Document (CARD)	Includes payload carrier and support hardware
Power	**< 1 Kw**	Cx 70000 Constellation Architecture Requirements Document (CARD)	Redundant Power bus; available power is mission specific
Volume	2.92 m^3	Cx 70000 Constellation Architecture Requirements Document (CARD)	
Data Rate	**< 30 Mbps**	Cx 70000 Constellation Architecture Requirements Document (CARD)	Standard Data interface; data rate is as available based on other mission requirements
Thermal	**Passive**	UPC-Orion introduction document, May 2, 2008, Bruce Milam	Carriers cannot impose a thermal load on Orion
Field of View (fixed pallet only)	**Mission Dependent**	Zenith, through Nadir is referenced in Introduction to UPC-Orion, May 2, 2008, Bruce Milam	driven by ISS docking configuration

3.2 Lunar Missions

Figure 3-5 represents the preliminary concept of an Orion mission to the lunar orbit and the Altair lander to the lunar surface.

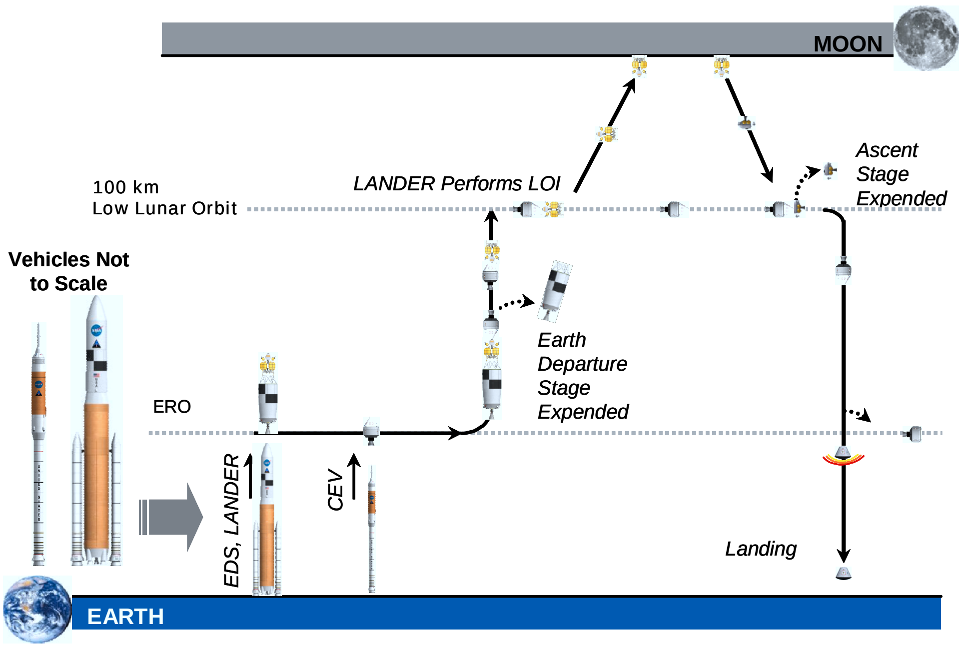


Figure 3-5: Lunar Design Reference Mission

A preliminary communications architecture has been developed for a secondary payload delivery for a lunar mission. The LEO case is well characterized, so the lunar option was addressed as a way to flesh out issues for the more difficult case. This scenario delivers a small payload to lunar orbit and shows GSFC MOC support for the UPC customer. Payload mission design life is estimated at three years, and support includes operations for spacecraft monitoring and control (command and telemetry paths) as well as science data receipt. Table 3-2 contains guiding assumptions for the example lunar mission including all operations and archive of data three years beyond the mission end. Figure 3-6 shows agency and customer roles and responsibilities for communication and data transmission.

Table 3-2: Example Lunar Mission Communication Assumptions

Mission Life: 3+ years
Housekeeping Data
Maximum assumed data rate of 1 Mbps
Includes S/C and payload data
Transmitted via RF link
Payload Data
Transmitted via Optical link
Up to 16 Mbps uplink
Up to 250 Mbps downlink
Option for up to 622 Mbps downlink
Daily downlink volume
≈ 22 Tbits/day maximum (assumes 250 Mbps downlink)
Raw archival storage = Life of the mission +3 years
Data Recovery:
Assume 98% recovery requirement (end-to-end)
Mission Operation Control (MOC)
Provides "standard" set of MOC functionality
CCSDS Format (Consultative Committee for Space Data Systems) spacelink
Science Operations Center (SOC) will provide all science data processing

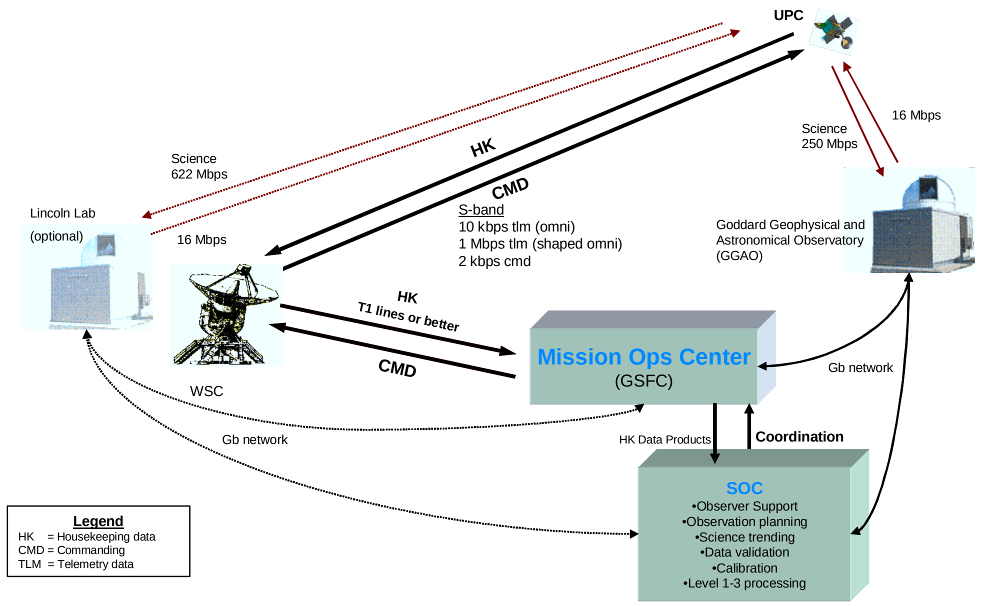


Figure 3-6: Mission Communications preliminary architecture concept

3.2.1 Lunar – Free Flyer/ejection payload

Lunar payloads sre subject to Orion lunar mass and power limits and are on the order of 382 Kgs, though Mission Design Lab models addressed payloads in the range of 80 – 382 Kgs. A payload is deployed/released from the SIM Bay and becomes a free flyer. It then continues its mission independently. This scenario is analogous to methods employed by the Apollo missions. Accommodation of the total mass delivered to lunar orbit is still a focus of feasibility studies.

3.2.2 Lunar – Fixed Pallet

Payload fixed pallet. A payload is fixed to a standard interface structure with Exploration Carriers, and remains with the vehicle for the entire mission. Mission duration is dependent on how long Orion remains in-situ during the mission, including loiter time in lunar orbit.

3.2.3 Lunar Payload Envelope

Table 3-3 below describes the envelop parameters for an Exploration Carriers lunar mission aboard Orion. The described payload envelop includes the Carriers payload, as well as mission kits that might include mechanical elements, thermal blankets, and/or release mechanisms. Actual Exploration Carriers envelop information for a specific Orion flight will be determined by the primary Orion mission parameters (i.e., intended orbit, crew size, etc.).

Table 3-3: Orion Lunar Mission Payload Envelope

Orion LEO/ISS Missions			
Parameter	**Capability**	**Source**	**Comments**
Orbit	**Mission specific inclination**	**Mission Manifest**	Payloads with lower constraints for orbit inclinations will have more opportunities for flight
Duration	**Variable**	CxP 70007 (Design Reference Missions) and Carriers MDL studies	

Mass	**< 382 Kg**	CxP 70000 Constellation Architecture Requirements Document (CARD)	Includes payload carrier and support hardware
Power	**< 1 Kw**	CxP 70000 Constellation Architecture Requirements Document (CARD)	Redundant Power bus; available power is mission specific
Volume	0.57 m^3	CxP 70000 Constellation Architecture Requirements Document (CARD)	
Data Rate	**< 30 Mbps**	CxP 70000 Constellation Architecture Requirements Document (CARD)	Standard Data interface; data rate is as available based on other mission requirements
Thermal	**Passive**	Introduction to UPC-Orion, May 2, 2008, Bruce Milam	Carriers cannot impose a thermal load on Orion
Field of View (fixed pallet only)	**Mission Dependent**	Zenith through Nadir is referenced in Introduction to UPC-Orion, May 2, 2008, Bruce Milam	

3.3 Expansion to Other Constellation Missions

Exploration Carriers payload envelopes for other components of Constellation will be defined as those architecture elements progress through their design. Other candidate elements include Altair lunar lander and the Earth Departure Stage (EDS) (Figure 3-7: Lunar transfer and Lunar orbit and surface Design Reference Mission addresses this capability. Also included below is a Mars Design reference mission (Figure 3-8) which includes all potential vehicles for secondary payloads. As these Constellation components progress through conceptual design, Exploration Carriers will develop appropriate Carriers payload envelopes suitable to meet scientific and technology payload needs.

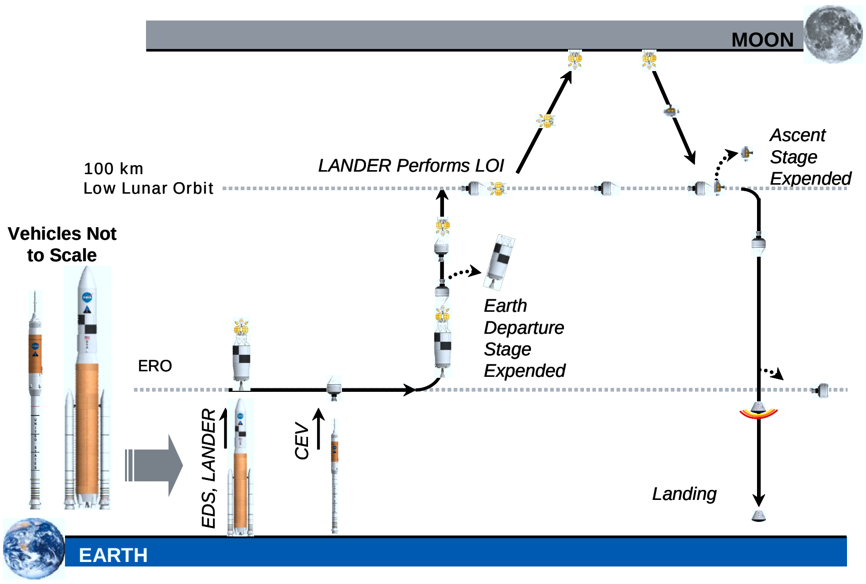


Figure 3-7: Lunar transfer and Lunar orbit and surface Design Reference Mission

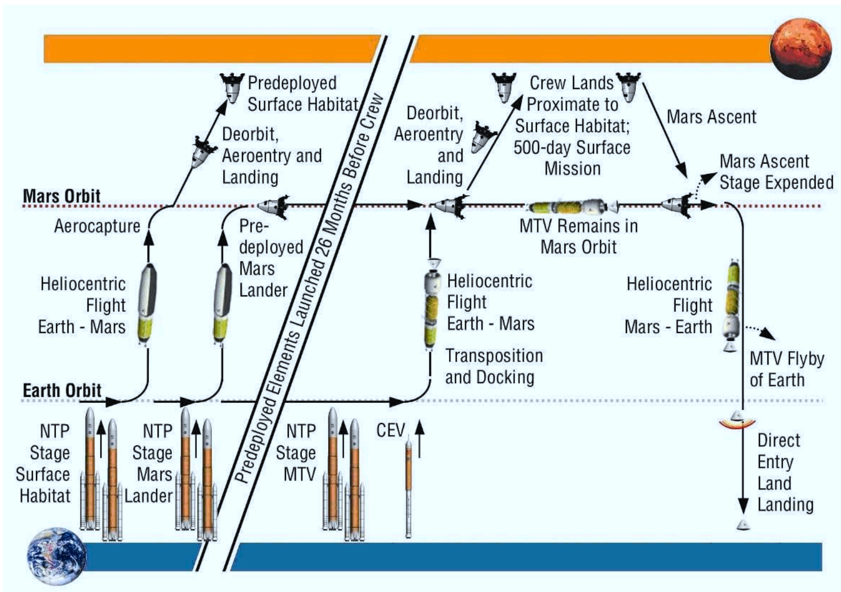


Figure 3-8: Mars Design reference Mission

3.4 Expansion to Other Missions

In the future, the Vision for Space Exploration will expand the horizons of Constellation toward the human exploration of Mars. Exploration Carriers will be uniquely positioned to support and continue applying the same concepts to those missions, offering an unprecedented opportunity to maximize the science and technology return of humankind's expansion into the solar system.

4. Payload Integration Process

The process for integration of payloads into the carrier and then the launch vehicle proceeds by phase of the specific Exploration Carrier payload project in parallel to the specific Constellation Architecture element, such as Orion. This process is consistent with the Constellation Program’s integration approach as currently defined, and will adapt to future changes in that approach.

For Orion-UPC, the Orion project has baselined Orion-UPC integration to occur 4 months prior to the launch date, occurring at Kennedy Space Center (KSC). To support this schedule, the payload will be delivered to Exploration Carriers at GSFC 1 month prior to that for integration and environmental testing required prior to installation in Orion.

Exploration Carriers will work with the payload PI and the Constellation Architecture project to ensure that all integration and testing requirements are completed successfully.

A key aspect of this process is the ability to accommodate a manifested payload four months after it is delivered to GSFC.

5. Conclusion

Exploration Carriers represents a unique national asset, building on a successful NASA legacy of utilizing available performance capabilities in the human spaceflight vehicles to achieve additional scientific and engineering objectives. By building upon the heritage of the Apollo SIM Bay and Space Shuttle Hitchhiker and Get Away Special projects, Exploration Carriers will keep the frontier of space open for critical science and technology experiments, those whose missions requirements require low-cost, quick-turnaround access to space.

Exploration Carriers provides an infrastructure and standardized process that provides science and technology users with a low risk solution. This solution maximizes NASA's investment in the Constellation Architecture, without impact to core missions.

This operations concept addresses feasible capability and schedule constraints within the Constellation architecture to realize science and technology secondary payload gains.

The initial emphasis for Exploration Carriers will involve payloads on the Orion spacecraft for LEO/ISS and lunar missions. Future opportunities will track with the evolution of the Constellation Program towards Lunar and Mars capabilities. It is envisioned that additional candidate vehicles may be included in the Exploration Carriers program, and Exploration Carriers will become the source of secondary payload services within NASA.

Exploration Carriers is in position to build on a proud tradition of augmenting human spaceflight with science and technology missions of opportunity.

Appendix A. Abbreviations and Acronyms

Acronym	Definition
AO	Announcement of Opportunity
CARD	Constellation Architecture Requirements Document
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
CM	Crew Module
CMG	Control Moment Gyroscope
CONOPS	Concept of Operations
CxP	Constellation Program
DRM	Design Reference Mission
EARD	Exploration Architecture Requirements Document
EDS	Earth Departure Stage
ESMD	Exploration Systems Mission Directorate
ESP	Exploration Systems Project
EVA	Extravehicular Activity
GAS	Get Away Special
GSFC	Goddard Space Flight Center
HGA	High Gain Antenna
I&T	Integration and Test
ISS	International Space Station
JSC	Johnson Space Center
LAS	Launch Abort System
LEO	Low-Earth Orbit
LSAM	Lunar Surface Access Module
Mbps	Megabits per second
MCC	Mission Control Center

Acronym	**Definition**
MDL	GSFC's Mission Design Laboratory
MOC	Mission Operations Center
NASA	National Aeronautics and Space Administration
ORU	Orbital Replacement Unit
PDR	Preliminary Design Review
PI	Principle Investigator
SA	Spacecraft Adapter
SDR	System Definition Review
SIM Bay	Scientific Instrument Module Bay
SM	Service Module
SMEX	Small Explorer
SOC	Science Operations Center
SSPP	Shuttle Small Payloads Project
SSRMS	Space Station Remote Manipulator System
STS	Space Transportation System
TLI	Trans-Lunar Injection
UPC	Unpressurized Cargo

Appendix B. Hitchhiker Program Value

Hitchhiker Experiments Accomplishments & Discoveries

HH-G1:	CPL	Characterized multi-power capillary pumped-loop heat transfer system operation in microgravity environment.
	PACS	Observed on-orbit containment to help assess impact on remote sensing from shuttle
	SEECM	Demonstrated improved reflectivity of pre-contaminated mirrors due to atomic oxygen
STP-1:	SKIRT	Characterized shuttle IR glow phenomenon as mostly nitric oxide and peaking in the ram direction
CGP	CryoHP	First flight demonstration of oxygen-based cryogenic heat pipe technology; provided first data of cryogenic heat pipes operating below 100K
	GLO-1	Observed up/down motion of the Earth's diurnal electric field, providing data on dawn/dusk asymmetry in ionospheric metal ion distribution; first simultaneous optical detection of metal (Mg) and its ion in a common volume of the ionosphere, helping in the identification of active chemical pathways
SHOOT:	SHOOT	First flight demonstration of cryogenic fluid transfer in space (liquid He at 720 l/hr); characterized operation of cryogenic technology components in a microgravity environment
COB:	CAPL-1	First flight demonstration of advanced capillary pumped-loop thermal control system for use on EOS and HST missions; characterized behavior advanced CPL in microgravity
	ODERACS	Provided opportunity to detect small objects in orbit with known characteristics to help calibrate ground-based radar systems used to monitor orbital debris
	BremSat	Characterized on-orbit atomic oxygen environment and electric charges produced by micrometeoroids
OAST-2:	CryoTP	First flight demonstration on nitrogen-based cryogenic heat pipe technology and a 120K phase-change thermal storage device; obtained more than 200 hours of thermal storage data
	SAMPIE	First retrievable high-voltage space plasma interaction experiment; first flight characterization of ISS and advanced photo voltaic solar cells; collected high-voltage plasma current data
	SKIRT	Confirmed that shuttle IR glow phenomenon peaks strongly in ram direction and goes to zero in anti-ram; discovered glow is suppressed by venting nitrogen gas
	TES-1	Obtained first data on long duration microgravity behavior of thermal energy storage fluoride salts; confirmed predicted salt void behavior; potential use for solar dynamic power systems
ROMPS:	ROMPS	Demonstrated commercial methods of rapid thermal processing of 100 thin film semiconductor materials in micrograviry; demonstrated robot control using capaciflector proximity sensor
CGP-O2:	GLO-2	Collected data on ionospheric metal ion clouds, allowing better understanding of ionospheric electric fields
IEH-1:	GLO-3	Observed ionospheric metal ion cloud build-up as function of time of day, providing insight into evolution of metal ion upwelling by Earth's electric fields
	UVSTAR	Acquired stellar UV spectra, demonstrating use of UVSTAR instrument for shuttle and space station
	CONCAP-IV-03	Characterized organic thin film growth with applications for electro-optics; confirmed thin-film growth in microgravity is very robust, allowing production of single-crystalline films
CAPL-2:	CAPL-2	Flight demonstration of advanced capillary pumped-loop thermal control system incorporating modified starter pump system
GPP:	GLO-4	Provided data to further understand altitude-dependent metal ion density in Earth's electric field

Appendix C. Glossary

Altair

Altair is the lunar lander component of the Constellation architecture, consisting of a descent stage and ascent stage. This lander will use both crewed and uncrewed configurations to support lunar exploration. Carriers payloads will be configurable on both.

Ares I

Ares I is the launch vehicle for Orion and delivers Orion into low earth orbit.

Ares V

Ares V provides the heavy lift capability for Constellation, required to support crewed lunar and lunar cargo missions. Ares V will lift Altair and the EDS into low-earth orbit for rendezvous with Orion and trans-lunar injection (TLI).

Earth Departure Stage (EDS)

The EDS is a component of the Ares V system, which serves as the system’s third stage, which facilitates LEO rendezvous with Orion and performs the system TLI burn. EDS also has a role in cargo-only lunar missions, performing direct TLI directly.

Exploration Carriers

The GSFC managed initiative to use capability present in the elements of the Constellation architecture to provide quick response, low cost access to space for science and technology missions

Orion

The Orion System consists of a Crew Module (CM), a Service Module (SM), a Launch Abort System (LAS), and a Spacecraft Adapter (SA), and transports crew and cargo to orbit and back. Initially, Orion will transport crew and cargo to and from ISS. Subsequently, it will transport crew and cargo to and from lunar orbit. This cargo can contain Carriers payloads in a SM internal bay and/or external attachment. In the future, derivatives of Orion will support missions to Mars. Orion offers the first opportunity for Exploration Carriers payloads.

Orion Cargo Bay

The Exploration Carriers payload envelope available for Orion LEO/ISS missions. This bay is located within the Service Module, occupying space that would house a propellant tank on lunar missions.

Orion SIM Bay

The Exploration Carriers payload envelope available for Orion lunar missions. This bay is envisioned to be smaller than the Orion Cargo Bay, and be attached external to the Service Module.

Payload ejection

A payload is deployed/released from Exploration Carriers and becomes a free flyer. It then continues its mission independent of Orion.

Payload extraction

During an ISS rendezvous mission, a payload is extracted from Exploration Carriers via the SSRMS and placed on the ISS. Additionally, in a LEO orbit that does not include ISS docking, an EVA may be performed to extract a payload, though this scenario is considered unlikely.

Payload fixed pallet

A payload is fixed to a standard interface structure with Exploration Carriers, and remains with the vehicle for the entire mission.

SIM Bay

SIM Bay was an Apollo-era capability. The Orion system will have an externally attached Carriers payload capability analogous to SIM Bay for lunar missions.

UPC

Unpressurized Cargo (UPC) refers to the Orion spacecraft's requirement to deliver Orbital Replacement Unit (ORU) cargo of up to 600kg to the ISS, and other cargo of up to 382kg to the moon. Exploration Carriers uses this baseline Orion capability to provide low-cost, low-risk opportunities for science and technology payloads.

Appendix D. References

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